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Reducing Uncertainties of Reservoir Fluid Due to Lack of Information for Optimum Production Activity Through Lean Sigma Process in Area X of Hevo Field

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ABSTRACT: Area X of Hevo Field, operated by PT. XYZ, produces heavy oil and relies on steamflood as its enhanced oil recovery (EOR) process. Comprehensive subsurface data, particularly from open hole and surveillance logs, is essential to monitor steamflood progress. However, incomplete open hole log data in all wells has created uncertainty in identifying the current fluid conditions at the lower part of Haru Reservoir, hindering an optimal development and optimization plans.

To overcome this issue, a Lean Sigma approach using the DMAIC framework was applied to improve data completeness. Rather than performing costly well deepening and re-logging activity, the solution by utilizing Facimage and Offset Well Modeling, a financial benefit of cost avoidance approximately US$1,440,000 is achieved. Additionally, the initiative increased the confidence level of the heavy oil practitioners and reduced the time required to assess remaining reservoir opportunities.

This improvement process not only delivered technical and economic value but also demonstrated a replicable model for other areas of Hevo Field and beyond, with appropriate field-specific adjustments. The study highlights how data-driven process optimization can effectively reduce uncertainty and support better decision-making in heavy oil reservoir management.

KEYWORDS: Lean Sigma, Facimage, Offset Well, DMAIC, Open Hole Log, Surveillance

I. INTRODUCTION

Heavy oil, which is categorized as an unconventional oil due to its properties of high viscosity, has different characteristics than the common light oil. The overall Hevo Field has no gas production, instead a heavy oil properties with API gravity of 17-22° API which is classified as heavy oil (Katz and Dawson, 1997). To optimally exploit the heavy oil reserve in the rock layer, a primary recovery is not sufficient as the fluid is too viscous to be produced without any support from the tertiary process. For heavy oil field, The most distinguishable production feature is the very limited recovery which a primary and secondary recovery can gain, thus tertiary recovery is essential for optimum recovery process which can recover until 90% of oil in the reservoir (Almahfood and Bai, 2008). PT. XYZ's Hevo Field has been adopting a steamflood recovery process as the Enhanced Oil Recovery (EOR) method. However, Area X has limitations in open hole log data acquisition which have hindered accurate interpretation of the reservoir's current fluid conditions, especially at the lower part of Haru Reservoir. This deficiencies exists in all wells drilled in Area X, which at that time, the project design didn't incorporate a proper drilling design to have an adequate rat hole for the logging activity to be done in a proper way. With the inadequate open hole log data received from the logging activity, significant challenges for efficient hydrocarbon recovery impairs the decision-making in strategizing the optimization and development plan, particularly when data uncertainty is high.

Hevo Field has several types of drilled well, which are producer, steam injector, and observation well. Observation well, in particular, is intended to be the eye of the reservoir, which monitor the progress of the steamflood progress. The observation well serves as the eye of the reservoir with its surveillance log that is conducted annually, yet the surveillance log result needs to be validated by the initial open hole log of the observation well to be properly used. Observation wells helps the heavy oil practitioners in devising a proper plan for optimization and development strategy to be effective and efficient, but due to the improper drilling design, the lack of open hole log data in observation well makes it cannot be fully utilized to see the condition of the current reservoir fluid. This lack of subsurface clarity has led to suboptimal surveillance validation, reduced confidence in operational decisions, and a potential loss production opportunity (LPO) of up to 4,532 MBO. To address this critical gap, this research applied the Lean Sigma methodology to identify, analyze, and mitigate the root causes behind incomplete log acquisition.

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The primary objective is to provide a cost-effective, efficient, safe, and reliable solution for enhancing reservoir data quality without necessitating costly interventions such as re-logging activity or deepening the current total depth of each wells. Through structured analysis and process improvement, this study offers a scalable solution for minimizing data uncertainty and improving the confidence level for the heavy oil practitioners in reviewing the remaining opportunities in the reservoir.

II. RESEARCH QUESTION, OBJECTIVES, SCOPE AND LIMITATION

Through the identified problem that is currently encountered in Area X of Hevo Field, there are several question, objectives, and research scope and limitation that needs to be addressed in order to have a focused analysis to close the gap and reduce the inefficiency/defect.

A. Research Question

1. What is the actual condition of the reservoir after the implementation of the improvement process?
2. What is the confidence level of the Area X team member in analyzing the reservoir current condition using the currently available data?
3. Will the actual reservoir condition bring benefit or loss for PT. XYZ?
4. How much is the potential cost or benefit for PT. XYZ if this research is implemented?

B. Research Objectives

1. Reduce surveillance log information uncertainties by identifying the issues and deliver a proposed solution to better understand the reservoir current condition.
2. Increase the confidence level of Area X team member in analyzing the reservoir current condition through improvement process using Lean Sigma methodology.
3. Analyze the potential benefit for PT. XYZ through Leans Sigma process by selecting the best possible options to improve the open hole log data for Surveillance log validation.
4. Quantify the potential cost or benefit gained by doing this research for PT. XYZ including the tangible and intangible aspects.

C. Scope and Limitation

1. Data usage in the research is limited to:
   - Primary data such as information of Area X of Hevo Field and drilled wells data of Area X including log data, especially the 8 TOWs as part of the improvement target.
   - Secondary data such as company's internal report which relevant to the topic, literature study especially on Lean Sigma process, and supporting data for tangible and intangible aspects other than BOPD.
2. This research method will be using Lean Sigma Process with DMAIC as its framework (Define, Measure, Analyze, Improve, and Control).
3. The scope of this research in improving the open hole log information for Surveillance Log validation are log data, deepening existing wells, drilling new well, and the quantification of cost and benefit including the tangible and intangible aspects.

III. METHODOLOGY

To have a valid surveillance log, a good quality open hole log data is needed to validate the surveillance log result. Bad quality subsurface data will increase the uncertainty of underground geology which will have implication of increasing the risk of oil and gas well drilling failures and other potential impacts for the company such as operational, tactical, and even strategic impacts (Desma et al., 2022). Having a complete and good quality open hole log is pivotal in acquiring a valid surveillance data, which the open hole log data needed to validate the surveillance log are gamma ray, resistivity, and porosity log (RHOB and NPHI) which those logs are usually taken from the Triple-Combo logging tool from the service company (Petrosync, 2024).

Mitigating the identified problem, a Lean Sigma methodology through the DMAIC (Define–Measure–Analyze–Improve–Control) framework to guide its structured problem-solving approach is implemented in this study (figure 1). Determining each components of DMAIC will guide through problem identification, root cause analysis, solution implementation, and a long-term control of improved process (George, 2002). This methodology focuses on reducing variance and eliminating inefficiencies in the well data acquisition process. The benefit of implementing Lean Sigma methodology as problem-solving process is having a systematic and orderly of thinking process from defining problems, execution, to monitoring process which the whole process delivers increasing problem understanding, delivering result in a safe, fast, better, and lower cost (Buell and Turnipseed, 2004). Each phase of DMAIC was tailored to suit the reservoir engineering context and was validated through field data, internal surveys, and reservoir modeling simulations. Complementing the Lean Sigma methodology implementation, the data will be collected through quantitative and qualitative method involving a primary data gathering through close- and open-ended employee survey, while the secondary data will be from company's report, logging data collection, and cross company's economic value of solutions offered.

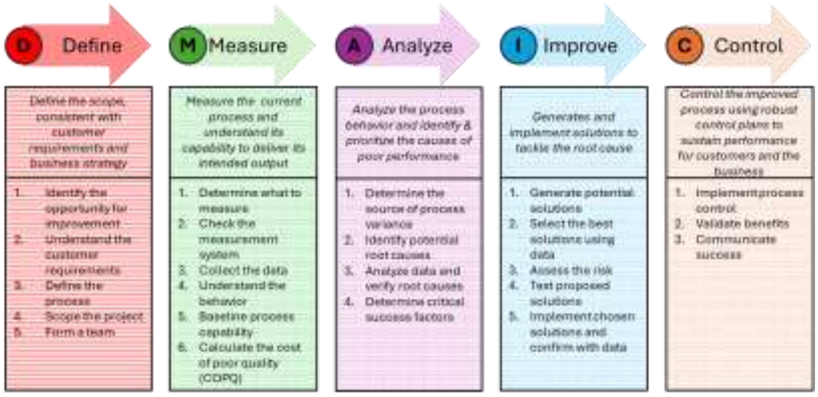

Figure 1.DMAIC methodology and components for each phase in Lean Sigma decision-making process (PT. XYZ internal training material, 2013).

IV. RESULT AND DISCUSSION

A. Define Phase

The main problem identified in this research is the lack of complete open hole log data in all drilled wells of Area X Hevo Field, especially in eight observation wells which its role is as a control of the current reservoir condition. With this limitation, the observation wells was captured as the primary cause of uncertainty in steamflood reservoir management review and monitoring process. Those eight observation wells failed to capture the critical lower-reservoir intervals, impeding the validation of surveillance logs such as Carbon/Oxygen (C/O), Thermal Neutron Porosity (TPHI), and temperature profiles (figure 2).

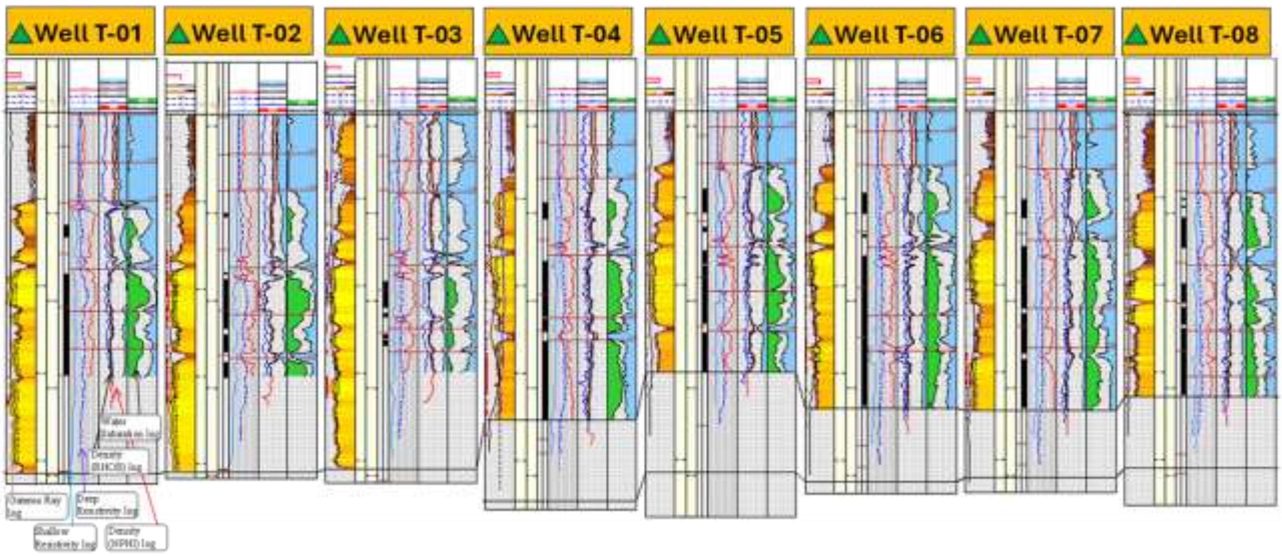

Figure 2. Eight observation wells in Area X showing different deepest and shallowest first-reading log data in each wells.

Each observation wells has missing/incomplete log data due to the inadequate rat hole space for the logging tool to cover the whole Haru Reservoir intervals and some observation wells has different log that has the deepest first-reading log data. In the missing logs interval, some observation wells has gamma ray log as its deepest first-reading log, while others have resistivity log as its first-reading log data. The difference on the first-reading log data was caused by different logging service company that was assigned to log the wells in the drilling program. The decision on why using different logging service companies is already captured in the project plan by the team member at that time to minimize the time taken to finish the project. The target of this research is to fill the missing log data in the observation wells so that a surveillance log activity can be done and validated until the very bottom of the available data.

Through identifying the problems, a set of goals to be improved can be devised by using a simple IPO diagram. The input section in IPO diagram are the basis of the problems identified, while the output section is the desired outcome from the improvement process implementation (figure 3). The desired outcome from the improvement process is the reduced number of observation wells with incomplete open hole log data, reduce the improvement cost implementation, reduce the review time of heavy oil practitioners in reviewing subsurface opportunity, and increase the confidence level of the heavy oil practitioners.

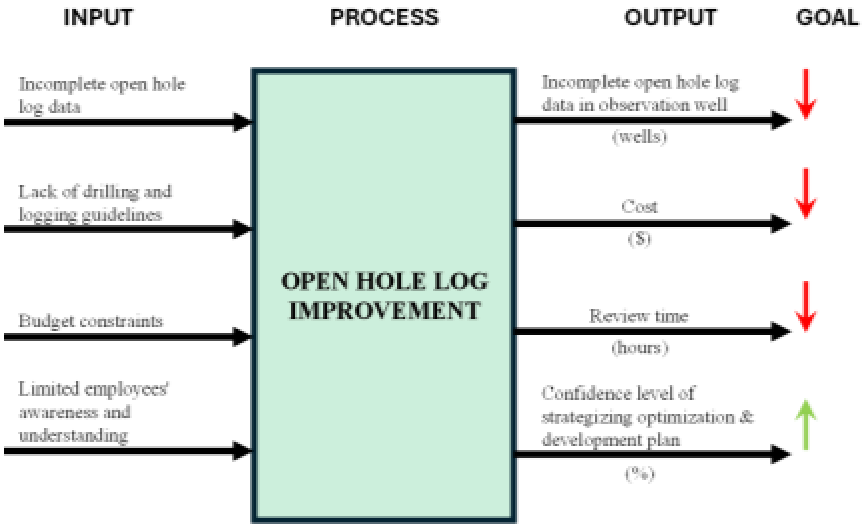

Figure 3. IPO diagram of the research with goal target of improvement.

B. Measure Phase

Measure phase is quantifying the baseline performance as benchmarks of the current process which then establishing objective metrics after the improvement to be evaluated. In this phase, the measuring tools that will be used are COPQ (Cost of Poor Quality) analysis, Process Flow Mapping, and Employee Survey tool. These tools that will be used in the Measure phase will help in quantifying the matrix of the goals identified in the IPO diagram in the Define phase.

1) COPQ (Cost of Poor Quality) Analysis: One of the tools in Lean Sigma that best to quantify the financial impact of the defects and inefficiency in the research is by using the Cost of Poor Quality (COPQ) analysis. In the COPQ analysis there are activities of collecting data to understand the current state of the process, identifying areas where quality issues occur, and measuring the associated cost. The COPQ analysis in this research will quantify the financial burden that are associated with the incomplete open hole log data. In the COPQ calculation, the accounted activities will be deepening the existing of producer and observation well which is taking the average of 5 days of execution and the average of oil loss 15 BOPD from the existing producer wells. The number of wells that will be accounted for is the 40 producer wells and 8 observation wells, with $70.55 of oil price.

Inputs:

n = number of observation wells

y = number of producer wells

deepening = cost for deepening the existing total depth of observation wells

logging = cost for conducting logging to cover the missing log intervals

z = number of days of rig for drilling and logging job

LPO = average of lost oil due to shut in producer wells

$ = oil price ($70.55/barrel)

days = time duration for deepening and logging job activities

$$COPQ = [(n+y) \times deepening] + [(n+y) \times logging] + (y \times LPO \times days\ \$)$$

$$COPQ = [(40+8) \times \$100{,}000] + [(40+8) \times \$80{,}000] + (40 \times 15BOPD \times 5\ days \times \$70.55)$$

$$COPQ = \$4{,}800{,}000 + \$3{,}840{,}000 + \$211{,}650$$

$$\mathbf{COPQ = \$8{,}851{,}650}$$

From the calculation of COPQ above, the total impact by executing deepening existing hole and conducting logging in producer and observation wells is US$8,851,650. This is a huge amount of money for the company to be spent for the exchange of additional information on the missing open hole log data. This amount of money is comparable to drilling 8 new infill wells project which cost average US$1 million per well.

2) Process Flow Mapping: A key analytical tools in Lean Sigma methodology to displayed a structured visualization on the process of how inputs, activities, and decision are combined to produce a specific output. This tool will help in visualizing the process of how the current condition is happening systematically from the planning until the result of the execution (figure 4). The process flow map shows that the gap which cause the missing/incomplete data at the lower part of the reservoir might come either from planning the drilling depth determination, budget constraint, or the unawareness of the project team to include the rat hole needed for the logging tool to read the bottom-most reservoir. By decomposing the end-to-end workflow into discrete stages, the analysis provides clarity on the interactions between the Well Development (WD) Team, Asset Reservoir Management (ARM) Team, and other supporting functions responsible for delivering high-quality log data. The Process Flow Map revealed that while certain steps, such as drilling execution and initial wireline logging are performed consistently, critical control points and verification activities are either inconsistently applied or absent altogether. Specifically, the workflow often lacks mandatory rathole planning during the design phase, standardized acceptance criteria for logging completeness, and formal validation protocols before well release. These deficiencies mean that even when individual tasks are executed according to plan, the collective process fails to ensure that open hole log data fully cover the reservoir intervals necessary for reliable surveillance validation.

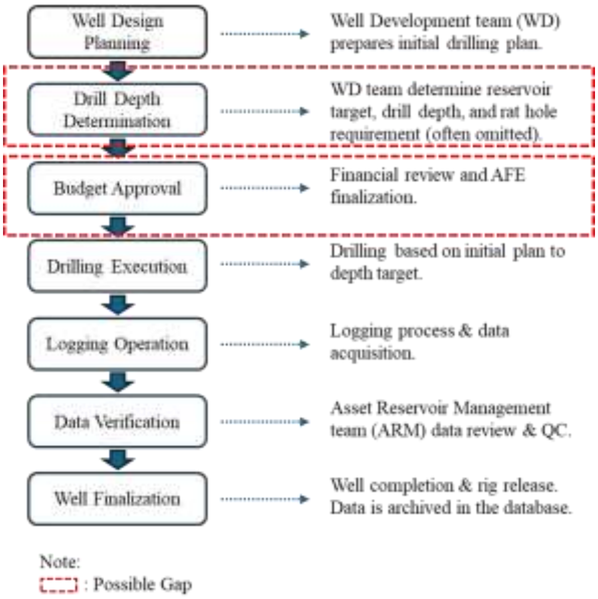

Figure 4. Process flow map of open hole log data acquisition process.

3) Employee Survey: A survey which is conducted to complement the quantitative analysis of COPQ and Process Flow Mapping in order to capture the perceptions, experience, and insights of key personnel involved in the process of this research. The rationale for incorporating a survey instrument is rooted in the understanding that process deficiencies are often influenced not only by formal procedures but also by informal practices, tacit knowledge, and cultural factors within the organization. The survey conducted for the research consist of two types of questions, which are close- and open-ended questions. The questionnaire of close-ended questions uses a five-points Likert scale and multiple-choice questions to assess the perceived impact and frequency of specific causal factors identified in the problem identification phase. Additionally, an open-ended questions were included to allow respondents to elaborate on the context-specific issues and propose suggestions for improvement. Analyzing the survey data helped validate the Process Flow Mapping findings and ultimately strengthened the evidence base for prioritizing targeted corrective actions. This multi-perspective approach ensured that recommendations would be both technically robust and operationally realistic.

Based on the conducted survey, there are some factors that are deemed as significant/extremely significant by the majority of respondents: the inadequate drill depth design, inadequate rat hole for logging activity, lack of standardize drilling/logging procedures, unawareness/inadequate understanding of log acquisition needs, and the insufficient cross-department coordination (figure 5). These factors are perceived as primary root causes of the incomplete log data, suggesting a structural and procedural deficiencies in well planning and cross-functional alignment. The moderately critical factor is the heavy reliance on historical/existing information from old wells which even though it is perceived a strong significance, there are some respondents that deemed that is not significant/extremely insignificant. This indicates that while historical information is powerful, an overly reliance to the historical information without new data, it will restrict the action for the heavy practitioners have. The factor with the least critical factor based on the survey is the budget constraints as it shows a notable responses with not significant and even extremely not significant responses. This implies that budget is not the primary root causes to the incomplete log data. The overall result of the survey shows that the root causes for the incomplete log data is primarily more in the technical planning and communication and least on the financial aspect.

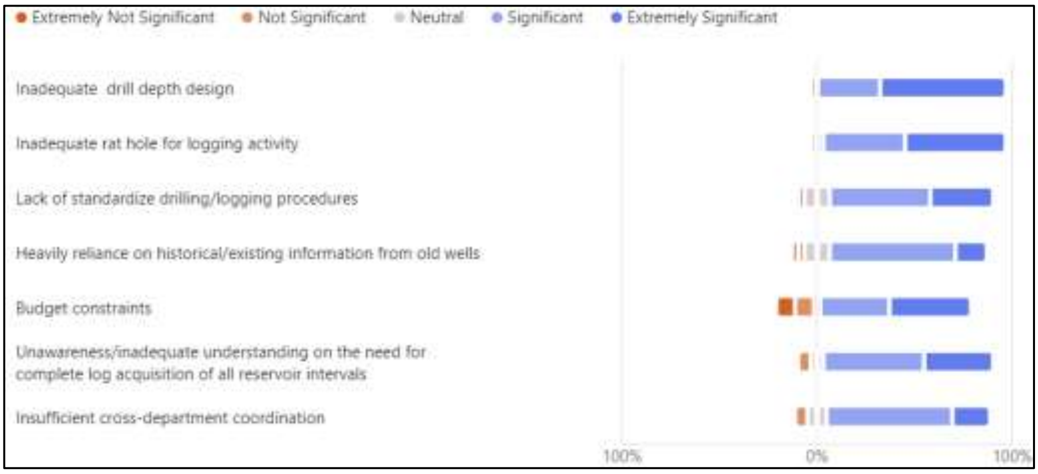

Figure 5. The employee survey results showing the responses of 31 respondents on the most contributing factors to the incomplete open hole log data.

Another follow-up questions to the factors that may contribute to the missing open hole log data is conducted, which are about the confidence level of the heavy oil practitioners in reviewing the remaining oil potential or the possibility of water zone in the rock layer and how long it will take for each of respondent's time to review it. Figure 6 shows a clear result of a less confidence of identifying the reservoir remaining opportunity if there is an uncertainty in the data information and most people will take more than 1 hour just to identify the remaining opportunity in the rock layer. This deficiencies is the main reason this research is conducted, which is to reduce the uncertainties from the lack of data for a higher confidence level and less review time for the heavy oil practitioner to do a review. This result will serve as a benchmark for the improvement goal target, which is to increase confidence level and to lower the time taken to review the remaining opportunity in the reservoir.

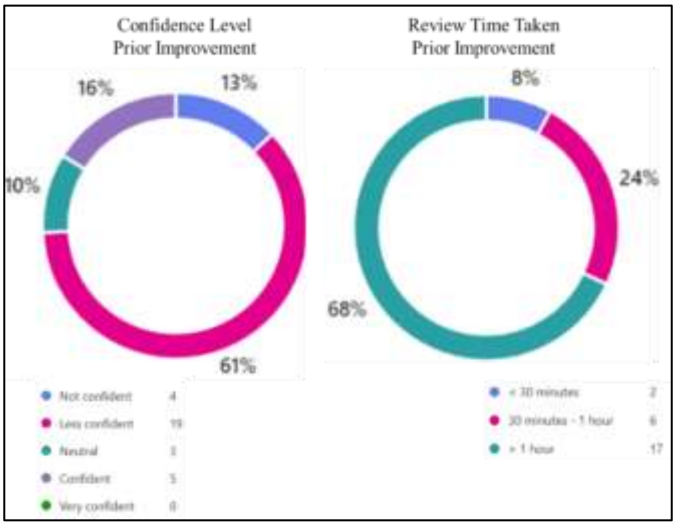

Figure 6. Heavy oil practitioners' confidence level and time taken for a comprehensive review with missing data from the open hole log.

C. Analyze Phase

In the Analyze phase, a comprehensive evaluation is conducted to identify the root causes contributing to the incomplete open hole log data acquisition in Area X of Hevo Field. This phase aims to investigate and validate the most significant variables resulting in the data deficiency by utilizing the employee survey results and the Pareto analysis. By quantifying and categorizing these factors, from technical design flaws and procedural inconsistencies to organizational coordination, the analysis provides a structured foundation for selecting the most effective corrective actions. The insights from his phase act as a critical information to ensure that the subsequent improvement is precisely targeting the problems and reaching the expected goals.

1) ***Pareto Analysis:*** An analysis to quantify the relative impact of each contributing factors, demonstrating that a small number of root causes accounts for the majority of observed defects. The result of Pareto analysis will then be used to determine the factors that are the most responsible for success and then focuses on them to improve the results. The Pareto analysis will rank each of contributing factors by frequency and perceived impact through the conducted employee survey. From the survey conducted, the main contributor for the incomplete open hole log data are from 3 main factors: inadequate drill depth design with 96.80% contribution, followed by inadequate rat hole for logging activity with 93.50%, and awareness/inadequate understanding on the need for complete open hole log data at 87.10% (figure 7).

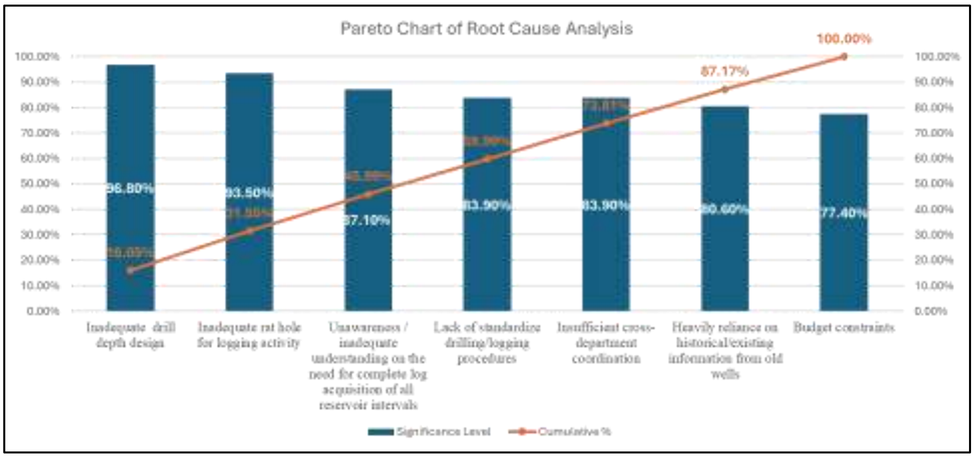

Figure 7. Pareto analysis of the root cause of the research problem.

2) ***Business Solution:*** Based on the problem identification, measured COPQ, employee survey, Pareto analysis, and Fishbone diagram, there are 3 alternative solutions that can answer the problem at hand, which are extracting data from the existing static geological model, running ELAN (Elemental Log Analysis) and cased hole gamma ray log, or creating synthetic log from surrounding wells. Each alternative are considered without drilling additional depth, but utilizing the available data until total drilled depth, which has its own pros and cons as shown in table 1. From the list of available alternative solutions, the most probable solution to be implemented with less cost, lower uncertainties, and less risk is the third option. This best alternative solution was taken due to the first and second option is currently not eligible to be done for its high uncertainty level of the first solution and no budget granted to conduct a re-logging job (second option) in Area X. Implementing the third option, which creating synthetic log from surrounding well data is the most feasible options, thus this option is taken as the best solution to solve the current problem. With that limitation, the detailed business solution will be described in the Improve phase of the Lean Sigma methodology section.

Table 1. Alternative solutions, pros and cons for the research.

No.	Alternative Solution	Pros	Cons
1	Extract from existing geological static model	Easy and no cost required	The sampling data is too big which can cause the synthetic log looks blocky
2	Run ELAN and Cased Hole Gamma Ray log	Actual reservoir data	Need to run log which costs ~ US$75,000 per well
3	Create synthetic log from surrounding	Data might be similar to actual condition	Might be hard due to sparse well spacing

D. Improve Phase

With the identified root cause of the problems through several Lean Sigma tools as well as the decision to implement the third alternative solution which is creating synthetic log from surrounding well data, there needs to have a flow process for the improvement plan. The improvement plan will focus on the currently available log in the observation well and surrounding well that has the availability of complete log data. The improvement plan will be implemented through a trial in one of the observation well and later to be implemented to the other observation well if the result is acceptable. In this research, in order to generate an acceptable synthetic log, a modeling technique of Facimage as well as Offset Well modeling will be implemented. As described in the Define phase that the availability of the open hole log in the observation wells are different from one another, thus the Facimage modeling and Offset Well modeling technique are meant to complement and validate one another as of to control the limited data variables which to generate the synthetic log.

The synthetic log modeling flow process starts from data QC to identify the available data from the observation wells and will be continued by conducting the Facimage modeling if there is a gamma ray log available. When there is no gamma ray log data available in the observation well, an analog data log will be used from the surrounding well through the Offset Well modeling. The usage of gamma ray log as a reference is that the gamma ray is an essential log to determine the lithology of the rock layer which will determine the behavior of the density log RHOB and NPHI. Figure 8 shows the flow process of the improvement, which if there is a gamma ray log available in the well target, a Facimage modeling technique will be implemented and then a regional trend adjustment will be done so that the result is within the control limit of the region. When there is no gamma ray present in the target well, an Offset Well modeling will be implemented by taking an analog data from surrounding well which then will be continued by conducting the Facimage modeling to generate the density log RHOB and NPHI after an adjustment from the regional trend as control.

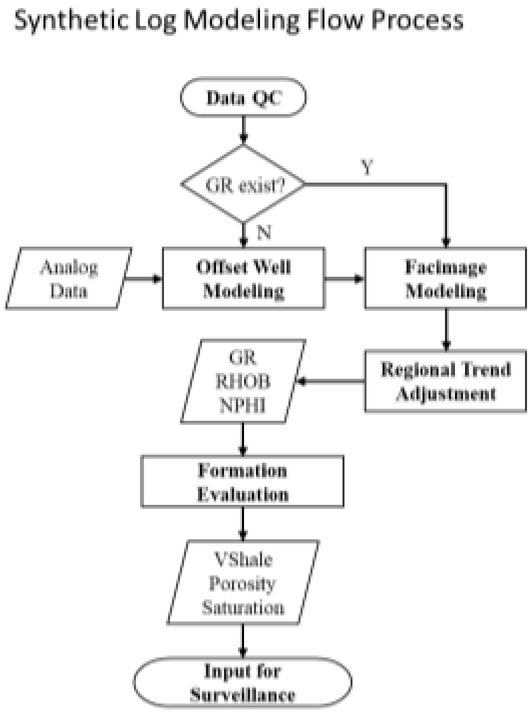

Figure 8. Synthetic log modeling flow process.

1) Facimage and Offset Well Modeling: A modeling technique to generate synthetic log for this research. Facimage modeling is a technique that utilizes electrofacies analysis and log prediction to characterize the rock properties. Facimage modeling involves clustering well log data into electrofacies and using statistical and neural network methods to predict reservoir characteristics like permeability and gas/ash content. Facimage modeling techniques identifies distinctive groupings (cluster) of model data (model logs) and establishes correlation (model) between the clusters and a known reference (associated logs) to predict new associated logs at new sample locations outside the training data set. For trial purpose, the Facimage modeling technique will be implemented first in observation well T-02 as it is one of the observation wells that has gamma ray log until the bottom of the hole with a missing density log (RHOB and NPHI) which will be created using the synthetic log. The Facimage modeling predicts the density log value by analyzing the behavior of the density log data corresponds from the gamma ray log data of surrounding wells relative to the distance of each wells.

The predictive result of Facimage modeling technique compared to the existing log data is shown in a crossplot chart which shows a highly positive relation with coefficient correlation of 0.936 (figure 9). Crossplot analysis is a method to visualize the relationship between two or more variables. The higher the positive coefficient correlation value between two or more variables, the stronger of the variables are positively related (Akoglu, 2018). A higher positive value of coefficient correlation result from the crossplot analysis, the more reliable formula/equation to be implemented for the Facimage modeling process.

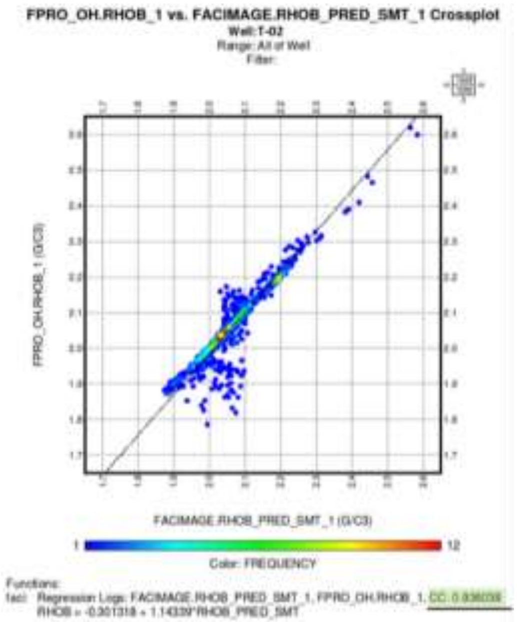

Figure 9. Relation between existing vs predictive density log (RHOB) data through Facimage modeling in observation well T-02 shows a highly positive relation with coefficient correlation 0.936.

After the Facimage modeling process is done, the log model generated from the Facimage model needs to be adjusted based on the regional trend as to make the result geologically coherent to the regional setting. This method acts as a validation measure as to validate the Facimage modeling result, which a high coefficient correlation of Facimage model may not necessarily geologically coherent to the regional setting. Adjustment to the regional trend for the generated log model through Facimage modeling technique is done by comparing it with a group of wells surrounding observation well T-02. From the regional trend adjustment process, the predictive log model generated through the Facimage modeling for both gamma ray and density (RHOB) log is acceptable with coefficient correlation above 0.81 (figure 10).

Gamma Ray   Density (RHOB)

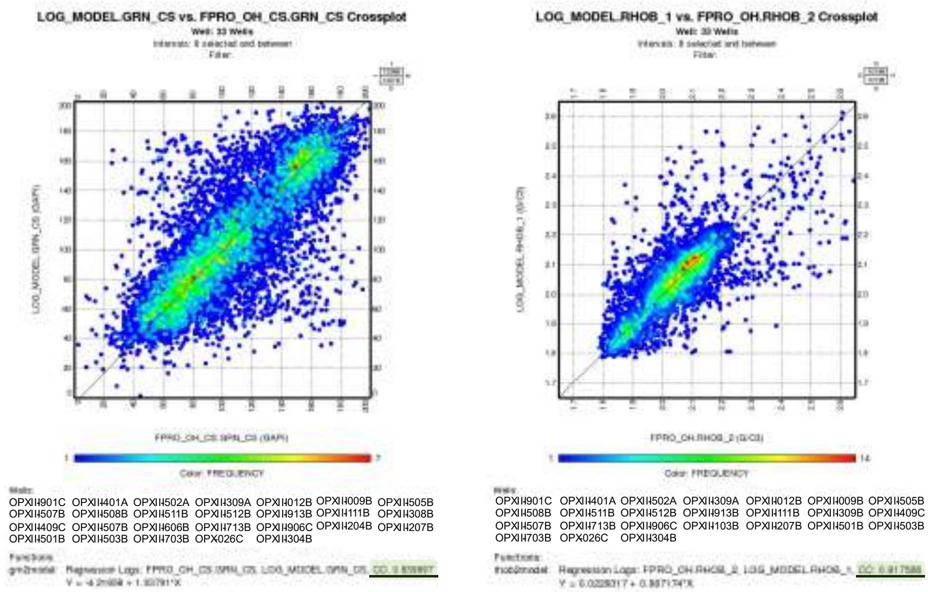

Figure 10. Validation process comparing between Facimage model and the other existing wells for gamma ray and density log (RHOB) resulting in a highly positive relation (CC above 0.81).

To validate the process of regional trend adjustment, the predicted log for gamma ray, density RHOB and NPHI through the Facimage modeling is generated in the other wells that has initially complete log data. This process is to verify whether the result of coefficient correlation > 0.8 in log data visualization is credible. The regional trend adjustment shows that the predictive log model conducted in another wells with the initially complete log data is relatively similar in pattern and magnitude. This result means that the Facimage modeling technique is acceptable to be implemented in the well with missing log data, which in this research is in the remaining observation wells. The regional trend adjustment result indicates that the predictive log model conducted in another wells with the initially complete log data is relatively similar in pattern and magnitude. This result means that the Facimage modeling technique is acceptable to be implemented in the well with missing log data, which in this research is in the remaining observation wells.

With the confirmed acceptable result of the Facimage modeling technique, The log model generated from the Facimage modeling is applied to observation well T-02 (figure 11). The result of the predicted log shown in figure IV.12 indicates that at the missing section of the observation wells is still an oil-prolific rock layer, thus the fearfulness of water zone at the lower part of Haru5 Reservoir is invalid. With this information, the lower Haru5 near observation T-02 still holds a great potential to be optimized/developed. For a more comprehensive lower Haru5 Reservoir information throughout Area X, this method needs to be implemented to other observation wells.

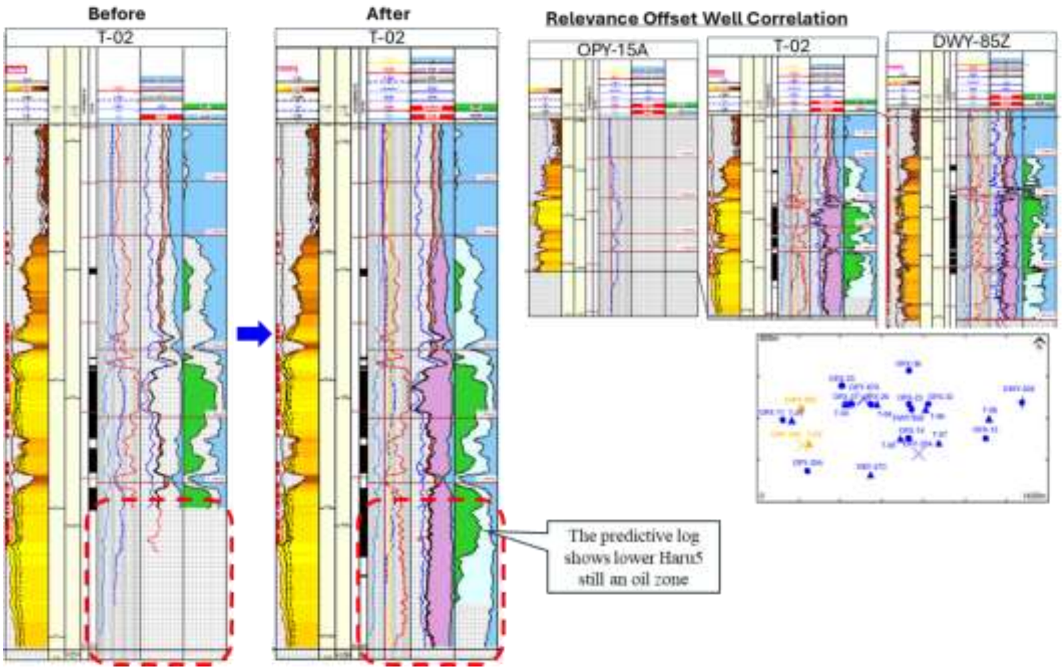

Figure 11. Facimage modeling result for T-02 with surrounding wells reference for data control.

While the Facimage modeling can be directly applied to the missing log wells that has gamma ray log, for other wells that has no gamma ray log exist at the missing log section, another approach is implemented, which is using the Offset Well modeling. This technique uses the nearby surrounding well information as an analog for generating the predictive gamma ray log. Since the gamma ray log model is created using the Offset Well modeling from nearby analog data, it is dependent on the distance between the target and the analog well, as the closer the distance, the more homogenic the geological condition. Once the gamma ray log model is created, then the Facimage modeling process is implemented to predict the density log for that well and finally getting adjusted through the regional trend data. This technique is applied to observation well T-05 which initially has no gamma ray log in the missing section. The result of the implementation of Offset Well modeling combined with the Facimage modeling technique is acceptable to predict the gamma ray as well as density log at the missing section.

E. Control Phase

The successful trial run application of the Facimage and Offset well modeling techniques to the observation well shows that these techniques is applicable to be implemented to other observation wells. By implementing these techniques to the other observation wells, a holistic view of the remaining opportunities in Haru Reservoir becomes more certain. Once the improvement process is fully implemented to the other observation wells, the surveillance logging activity that will be conducted as part of the annual review process, will use the improved open hole log data in each observation well as a validator of the surveillance log result. The result of the full implementation of Facimage and Offset Well modeling is shown in Figure 12. The observation well open hole log as it has improved shows an information that at the previously missing section, which was feared as a water zone, proved to be still an oil-prolific rock layer in all observation wells. This shows that Area X of Hevo Field still bears a good opportunity to be optimized and developed.

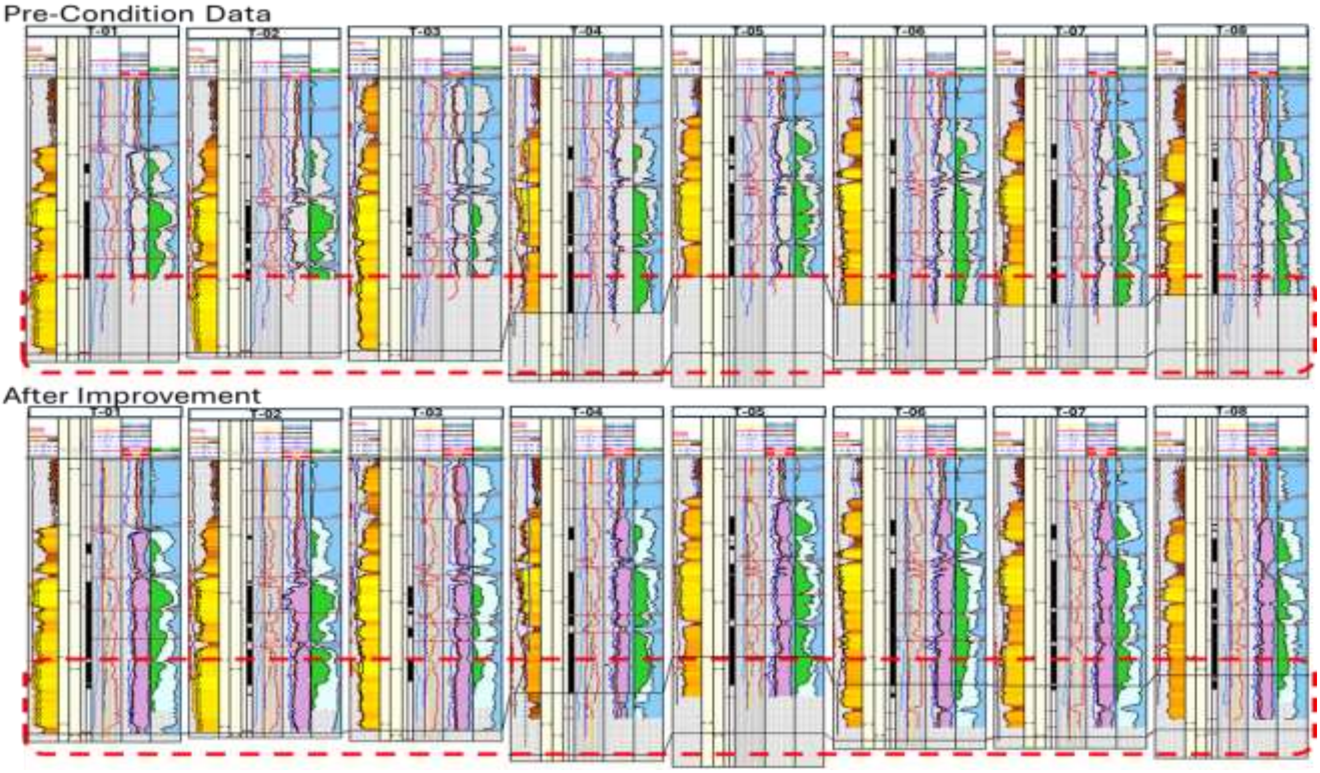

Figure 12. The pre-condition and after improvement result from all 8 observation wells in Area X Hevo Field.

With the improved open hole log, the previously captured problem which the surveillance log data cannot be validated due to no complete open hole log, can now be validated until the bottom most additional open hole log information. The validated surveillance log will then give information related to the current remaining oil opportunity in the reservoir. This information serves as a confirmation whether the lower Haru Reservoir is truly filled with oil or water which is the opposite of this research result. Figure 13 displays the result of surveillance log in observation well T-01 after being validated using the synthetic log is similarly showing an oil-prolific reservoir until the lower part of Haru Reservoir interval.

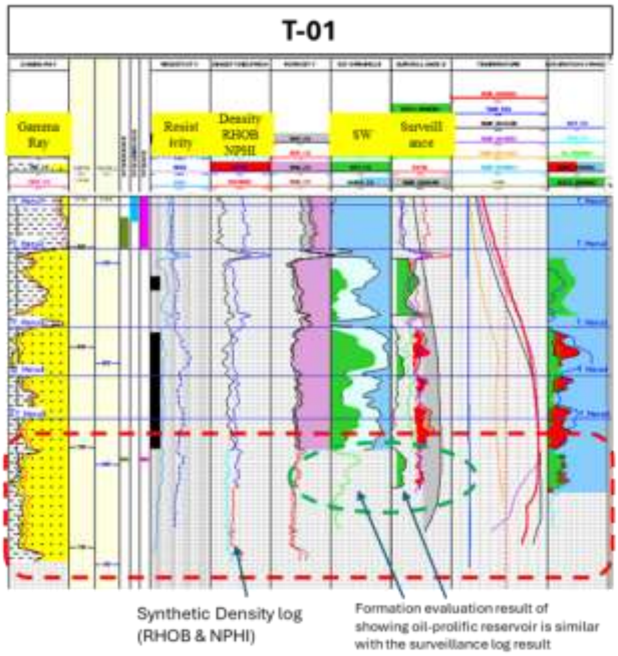

Figure 13. Synthetic log and the formation evaluation log result (SW) in observation well T-01 shows the similar result with the surveillance log of oil-prolific zone in Haru5 interval.

As part of the control phase, to understand and quantify the effect of the improvement effort that is implemented to reduce uncertainties in reviewing remaining opportunity in the reservoir, a post improvement survey is conducted. The result of the post improvement survey shows a significant improvement on both the confidence level of the respondent and the review time taken to analyze the remaining opportunities in the reservoir (figure 14). The post improvement survey result shows an improvement in confidence level, where previously was 61% less confident (19 respondents) to 65% confident and 35% very confident (11 respondents). An improvement in review time of the remaining opportunity in the reservoir also shows a significant improvement, where previously the majority of respondents are taking more than 1 hour to do a review (17 respondents) becomes less than 1 hour to do the review. Table 2 shows the quantified improvements of both confidence level and review time taken.

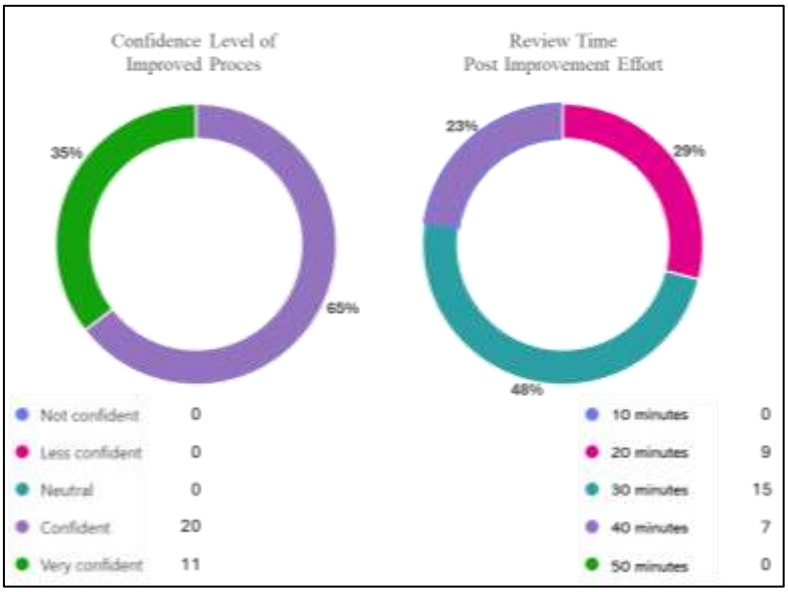

Figure 14. Post improvement employee survey results

Table 2. Improvements effort results in confidence level and review time.

Improvements	**Before Improvement (Majority)**	**After Improvement (Average)**
Confidence Level	**Less Confident**	**Confident**
Review Time Taken	**> 60 minutes**	**29.35 minutes**

CONCLUSIONS

The research was conducted to address a significant issue faced by PT. XYZ in the development and management of Area X in Hevo Field, which is the absence of open hole log data at the lower Haru Reservoir. This incomplete data caused high uncertainties in interpreting the current reservoir conditions, limiting the confidence of Asset Development Teams (AOT and WD) in strategizing proactive jobs or planning new developments. Through the Lean Sigma methodology, particularly the DMAIC framework, the root causes were identified, potential solutions were explored, and a cost-effective and technically sound improvement strategy was implemented. The conclusion drawn from this research highlights that the incomplete log data was primarily caused by inadequate well planning during the drilling design phase, lack of rat hole consideration, and poor awareness regarding the importance of log completeness for reservoir surveillance validation. By implementing the synthetic log modeling approach by using Facimage and Offset Well modeling, the research successfully filled the data gaps in the eight observation wells. This approach not only provided new insights into previously unrecognized oil-prolific zones but also enhanced the confidence level of the heavy oil practitioners and significantly reduced the time required for interpretation. It further led to validated surveillance logging, enabling a clearer picture of remaining oil opportunities and reservoir fluid distribution.

The result of the improvement process by implementing the Facimage and Offset Well Modeling through Lean Sigma methodology, the research questions that has been answered such as:

1. The actual condition of Haru Reservoir after the implementation of the improvement process is that Harus Reservoir still shows an oil-prolific zone in the rock layer. This eliminates the uncertainties which previously feared as a water zone.
2. The confidence level for heavy oil practitioners in strategizing for the optimization and development plan was significantly improved by the implementation of the improvement process from the majority of less confident becomes

confident in planning the proper program. This confidence level also brings a faster review time from the previously takes more than 60 minutes to review a reservoir opportunity becomes an average of 29.35 minutes.

3. Knowing the actual condition of Haru Reservoir in Area X of Hevo Field, which is an oil-prolific zone until the bottom of Haru Reservoir and confirmed by the surveillance log taken after the implementation, it is clear that Haru Reservoir in Area X still brings huge potential for exploitation which will benefit PT. XYZ.
4. As this research was done mainly to improve the open hole log data in the observation wells, the tangible benefit by implementing this improvement process is US$ 1,440,000 by avoiding drilling process to deepen the wells and conduct a logging job activity. If this process is implemented to the other wells in Area X or even expanded to other area which can implement this method, a much bigger value will benefit PT. XYZ.

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